Two planes on merging routes are:
-- traveling at the same speed.
An alternate route is not available.

LINEUP WITH MATH[TM]

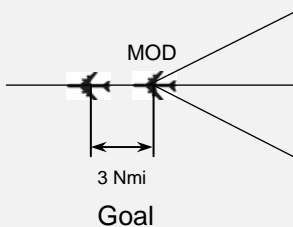## Math-Based Decisions in Air Traffic Control
for Grades 5 - 9

Problem Set E

Resolving 2-Plane Traffic Conflicts by Changing Speed

Teacher Guide with Answer Sheets

Overview of Problem Set E

MOD

3 Nmi

Goal

Estimated class time: 1-2 hours

In this Problem Set, students will determine whether two planes traveling on different merging routes will line up with proper spacing at MOD (the last intersection before the planes leave the airspace sector). If the spacing is not adequate, students will change the speed of one plane to achieve the proper spacing at MOD.

The planes are traveling at the same altitude and the same constant (fixed) speeds.

In *LineUp With Math*[TM], this is the first set of problems where students use speed change to achieve safe and proper spacing.

This Problem Set also introduces an optimal solution time for each Simulator problem. A "target time" is posted on the Simulator screen. This target is the minimum time required for the last plane to reach the intersection at MOD. An on-screen clock keeps track of the flight time for a student's solution.

Each problem can be explored with the interactive Air Traffic Control (ATC) Simulator. Five of the problems can be more closely examined with Student Workbook E (print-based). The Workbook provides a structured learning environment for exploring the problems with paper-and-pencil worksheets that introduce students to pertinent air traffic control concepts as well as problem analysis and solution methods.

Objectives

Each plane is traveling at 600 knots, the maximum speed allowed. So to resolve a spacing conflict, students must reduce a plane's speed.

Students will:

- Analyze a sector diagram to identify a spacing conflict between two planes, each traveling at the same speed.
- Resolve the spacing conflict by changing the speed of one plane.
- (Optional) Learn that a given percent reduction in plane speed yields the same percent reduction in distance traveled in the original amount of time. (For a mathematical derivation of this relationship, see Appendix III.)

Prerequisites

Before attempting the current Problem Set, it is *strongly* recommended that students complete Problem Set A that introduces essential air traffic control vocabulary, units, and representations.

It is also recommended that students complete Problem Set D that introduces students to the effects of changes in speed.

Materials

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- ATC Simulator (web-based)
- Student Workbook E (print-based)

The materials are available on the *LineUp With Math^{TM}* website:

> http://www.smartskies.nasa.gov/lineup

A separate student website gives students easy access to the Simulator only (and not to the answers and solutions provided on the teacher website):

> http://www.atcsim.nasa.gov

ATC Simulator

A complete description of the ATC Simulator is contained in the Educator Guide for LineUp With Math^{TM}.

For a Simulator quick start guide and an animated tutorial, visit the LineUp With Math^{TM} website.

Interactive Air Traffic Control Simulator

Students can explore Problem Set E with the interactive ATC Simulator. Each problem features a 2-plane conflict that can be resolved by a speed change.

The Simulator problems for Problem Set E are:

> 2-4*; 2-5*; 2-6*; 2-7*; 2-8*; 2-11; 2-12; 2-13; 2-14; 2-15; 2-16

Problems with an asterisk (*) are supported by worksheets in Student Workbook E.

The optimal solution time ("target time") is displayed on the screen for each Simulator problem. This time is the minimum required for the last plane to reach the intersection at MOD. An on-screen clock keeps track of the flight time for a student's solution.

For a complete set of answers and solutions to all Problem Set 5 Simulator problems, see Appendix I of this document.

For a discussion of the key points associated with the first five Simulator problems, see the worksheet notes in the following Student Workbook section.

Student Workbook

It is recommended that you have a copy of Workbook E open while you read these notes.

The worksheet title is the same as the associated Simulator problem.

The Student Workbook consists of five worksheets, one for each of the five featured Simulator problems listed below.

Simulator Problem	Worksheet Title
2-4*	Problem 2-4
2-5*	Problem 2-5
2-6*	Problem 2-6
2-7*	Problem 2-7
2-8*	Problem 2-8

Each problem features a spacing conflict with different starting conditions. As students progress through the worksheets, they likely will require less guidance and structure, and the worksheets reflect this.

For a complete set of answers to each worksheet, see Appendix II of this document.

For each worksheet, the key points are briefly described as follows.

Worksheet: *Problem 2-4: Assure Spacing Between 2 Planes*

*In the sector diagram, each route flows only **towards** MOD. E.g., a plane may fly from MINAH to OAL, but cannot fly from OAL to MINAH.*

- After students identify the spacing conflict at MOD, they determine it will take each plane 3 minutes to arrive at MOD. After students decrease the speed of one plane, the faster plane will still take 3 minutes to arrive at MOD. So, the planes will fly 3 minutes before Ideal Spacing must be achieved.
- To resolve the spacing conflict, students begin by reducing the speed of one plane by 60 knots. (Either plane can be selected since neither has a headstart.) At the reduced speed, this plane will travel 1 Nmile less each minute.
- Finally, students apply the 1 Nmi/minute distance reduction for 3 minutes to achieve Ideal Spacing (3 Nmi) exactly at MOD.

Worksheet: *Problem 2-5: Assure Spacing Between 2 Planes*

- Using the same problem-solving approach as in Problem 2-4, students determine it will take 2 minutes for each plane to arrive at MOD. After students decrease the speed of one plane, the faster plane will still take 2 minutes to arrive at MOD. A single 60-knot speed decrease will achieve only a 2 Nmi spacing in 2 minutes at MOD. This is less than Ideal Spacing at MOD.
- To resolve the spacing conflict, students must make a 120-knot speed decrease (the equivalent of **two** 60-knot decreases).
- This results in 4-Nmile spacing at MOD, which is greater than Ideal Spacing. The students are asked to suggest a way to achieve Ideal Spacing at MOD. This requires increasing the slower plane's speed to the same speed (600 knots) as the leading plane as soon as Ideal Spacing is achieved.
- In the next problem, Problem 2-6, students will be given the opportunity to make such a speed increase.

Worksheet: *Problem 2-6: Assure Spacing Between 2 Planes*

- Students use the same problem-solving approach as in Problem 2-4. However, unlike Problems 2-4 and 2-5, one plane has a headstart (1 Nmi). For the trailing plane, a single 60-knot speed decrease will result in more than Ideal Spacing at MOD.
- The 3-Nmile Ideal Spacing is achieved before MOD. As soon as this Ideal Spacing is achieved, the trailing plane's speed should be increased to the same speed as the leading plane. This will maintain Ideal Spacing all the way to MOD and beyond.
- Students are asked to specify the number of minutes (2 minutes) after which they will speed up the trailing plane. This is the number of minutes at which Ideal Spacing will be achieved.

In this problem, students work with decimals.

- Students use the same problem-solving approach as in Problem 2-6. However, in the current problem, both planes pass through OAL before they arrive at MOD. So students must check for Minimum Separation (2 Nmi) at OAL as well as for Ideal Spacing 3Nmi at MOD.

- First, students check for Ideal Spacing at MOD. This is because the goal is to have Ideal Spacing at MOD. After the students have determined the strategy to achieve this goal, they next check to see if their strategy violates Minimum Separation at OAL. (If it does, they must change their initial strategy to resolve the violation at OAL.)

- Since each plane is 25 Nmi from MOD, they will arrive at MOD at the same time. Since there is **no** spacing between the planes at MOD, this does not meet the Ideal Spacing goal (3 Nmi).

- To resolve the spacing conflict, students begin by reducing the speed of one plane by 60 knots. (Either plane can be selected since neither has a headstart.) At the reduced speed, this plane will travel 1 Nmile less each minute.

- The faster plane takes 2.5 minutes to travel 25 Nmiles to MOD at 600 kts. In 2.5 minutes, with a 60-knot speed reduction, the slower plane will fall behind 2.5 Nmi (2.5 minutes x 1 Nmi/minute = 2.5 Nmi). This is less than Ideal Spacing at MOD.

- To achieve at least Ideal Spacing at MOD, a 120-knot speed decrease is required. This speed decrease will yield a 5 Nmi spacing at MOD (2.5 minutes x 2 Nmi/minute = 5 Nmi).

- Before the planes reach MOD, they will each pass through OAL. So students must check for Minimum Separation at OAL. Each plane starts 15 Nmi from OAL. The faster plane takes 1.5 minutes to travel 15 Nmi to OAL. A 120-knot speed decrease (2 Nmi per minute) will result in a 3 Nmi separation at OAL (1.5 minutes x 2 Nmi/minute = 3 Nmi). This meets the Minimum Separation requirement of at least 2 Nmi. This also provides Ideal Spacing at OAL.

- To maintain the 3 Nmi Ideal Spacing all the way to MOD and beyond, students must speed up the slower plane exactly at OAL. (Note: Students made similar calculations in Problem 2-6.)

Worksheet (Optional): *Understand the % Method*

- A plane, traveling at its original speed, can cover a certain distance in a given amount of time. If the plane's speed is reduced by a certain percent, then in the given amount of time, the distance covered is reduced by the same percent. (For a mathematical derivation of this relationship, see Appendix III.)

- This percent relationship is especially easy to apply in the *LineUp With Math^{TM}* problems since all speed reductions are done in increments of 10% of the original speed. In particular, the original plane speed is always 600 knots and the original speed is always reduced in 60-knot increments. (Note: 60 is 10% of 600.) With a 10% speed reduction, the distance traveled is also reduced by 10% (of the original distance). To find 10% of the original distance, students need only divide the distance by 10, that is, they need only move the decimal point one place to the left.

- Note that with this percent method, students do *not* need to calculate the amount of time it will take the lead plane to reach MOD (as they have done in previous worksheets).

Worksheet (Optional): *Problem 2-8: Assure Spacing Between 2 Planes*

- In this problem, students are guided through the percent method introduced in the previous worksheet.
- The leading plane starts 20 Nmi from MOD. The trailing plane starts 21 Nmi from MOD. In the time it takes the leading plane to travel 20 Nmi to MOD, the trailing plane will also travel 20 Nmi. So to calculate the % decrease in travel distance for the trailing plane, students must use 20 Nmi (**not** 21) for the distance traveled.

Answer Sheets

For a set of answers and solutions to all Simulator problems, visit the LineUp With Math^{TM} website.

Answer sheets for each of the Problem Set E Simulator problems can be found in Appendix I of this document.

Answer sheets for each worksheet in Student Workbook E can be found in Appendix II of this document.

A mathematical derivation of the Percent Method can be found in Appendix III of this document.

LineUp With Math™

APPENDIX I

Air Traffic Control Simulator

Simulator Solutions for Problem Set E

2-4*, 2-5*, 2-6*, 2-7*, 2-8*,
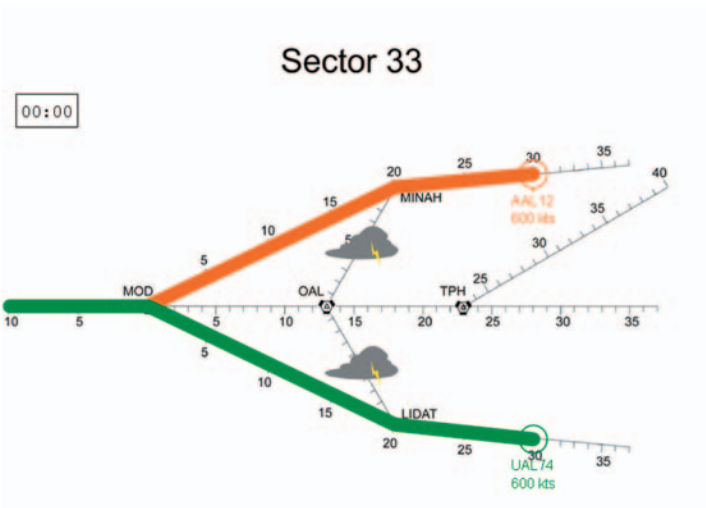## 2-11, 2-12, 2-13, 2-14, 2-15, 2-16

Problems with an asterisk (*) are supported by worksheets in Student Workbook E

Problem 2-4 — Solution

Starting Conditions:

Sector 33

00:00

Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	30	600
UAL74	LIDAT		MOD	30	600

- Route from **LIDAT** to **OAL** is closed.
- Route from **MINAH** to **OAL** is closed.
- Ideal spacing at **MOD** - 3 Nmiles

Analysis:

- **Conflict:** **AAL12 AND UAL74** will arrive at MOD at the same time.
- **Weather** prevents **AAL12** or **UAL74** from rerouting.
- **UAL74** or **AAL12** need to slow down to fall back 3 Nmiles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	30	0
1st	UAL74	30	

Initial:
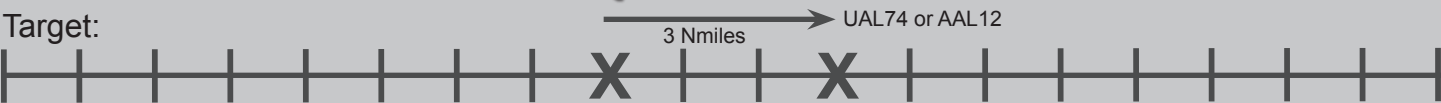
AAL12   UAL74

Target:

3 Nmiles → UAL74 or AAL12

X   X

Solution:

Sector 33

00:00

540 kts
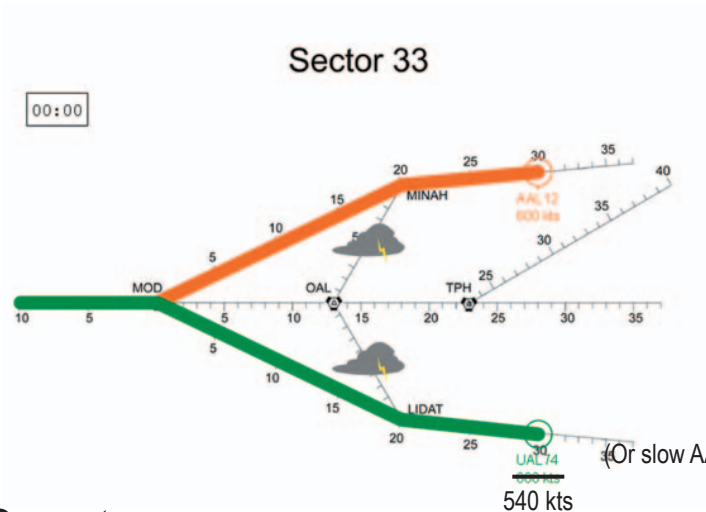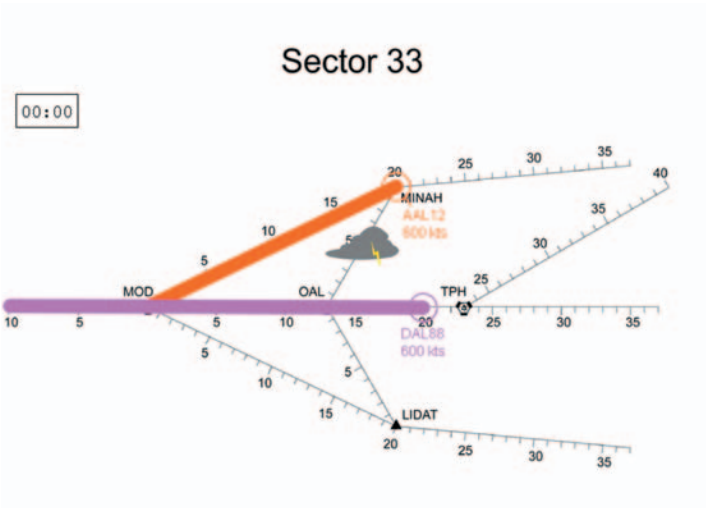
- **UAL74 or AAL12 -** Slow down to 540 knots for 3 minutes to fall back 3 Nmiles. Then speed up to 600 knots.
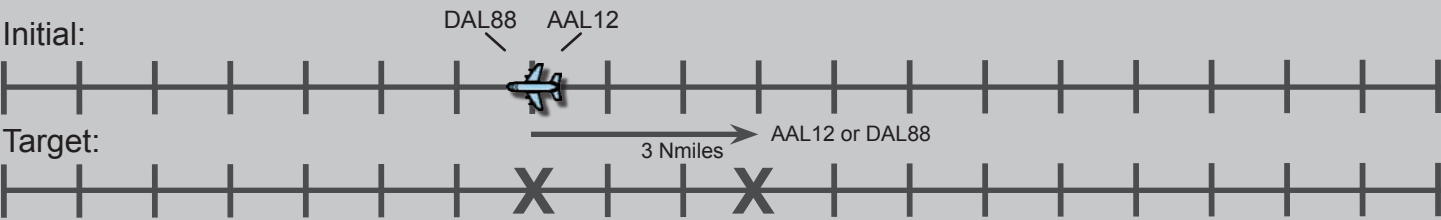
- **Target Time** - 3:18 mins.

(Or slow AAL12 to 540 kts.)

Problem 2-5   Solution

Starting Conditions:

Sector 33

00:00

Plane	From	Through	To	Distance	Speed
AAL12	LIDAT		MOD	20	600
DAL88	OAL		MOD	20	600

• Route from **MINAH** to **OAL is closed**
• Ideal spacing at **MOD** - 3 Nmiles

Analysis:

• **Conflict: DAL88 AND AAL12** will arrive at MOD at the same time.
• Weather prevents AAL12 from rerouting.
• **AAL74** or **DAL88** need to slow down to fall back 3 Nmiles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	DAL88	20	0
1st	AAL12	20	

Initial:

Target:

Solution:

Sector 33

00:00

480 kts   (Or slow DAL88 to 480 kts.)
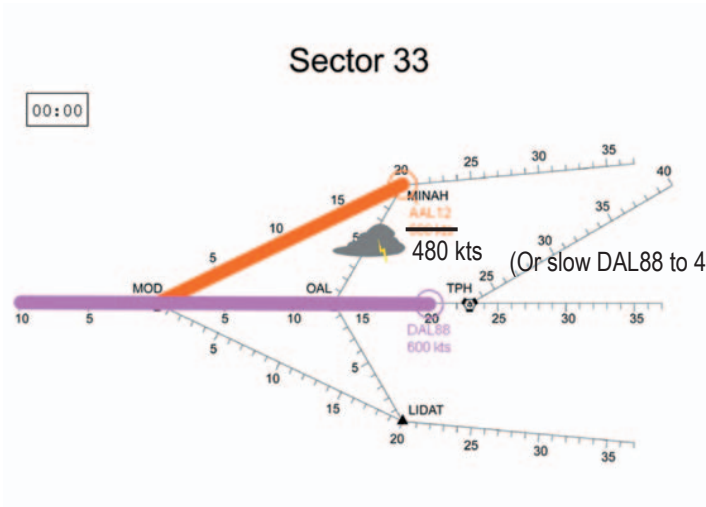
• **AAL12 or DAL88 -** Slow down to 480 knots for 1.5 minutes to fall back 3 Nmiles. Then speed up to 600 knots.
Note: Slowing to 540 knots would only result in falling back 2 Nmiles in the 20 Nmiles to MOD.
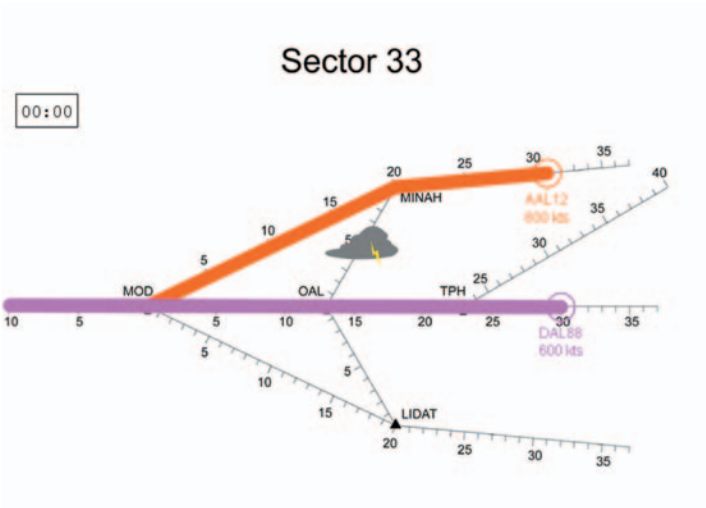
• **Target Time** - 2:18 mins.

Starting Conditions:

Sector 33

00:00

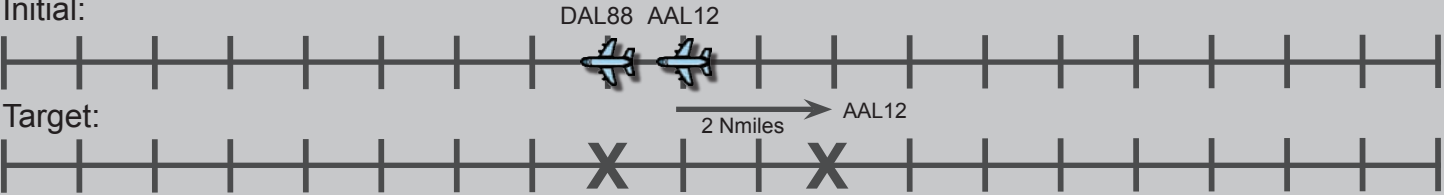| Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	31	600
DAL88	TPH	OAL	MOD	30	600

• Route from **MINAH** to **OAL is closed**.
• Ideal spacing at **MOD** - 3 Nmiles

Analysis:

• **Conflict:** **AAL12** will arrive at MOD **1 Nmile** behind **DAL88**.
• **Weather** prevents **AAL12** from rerouting.
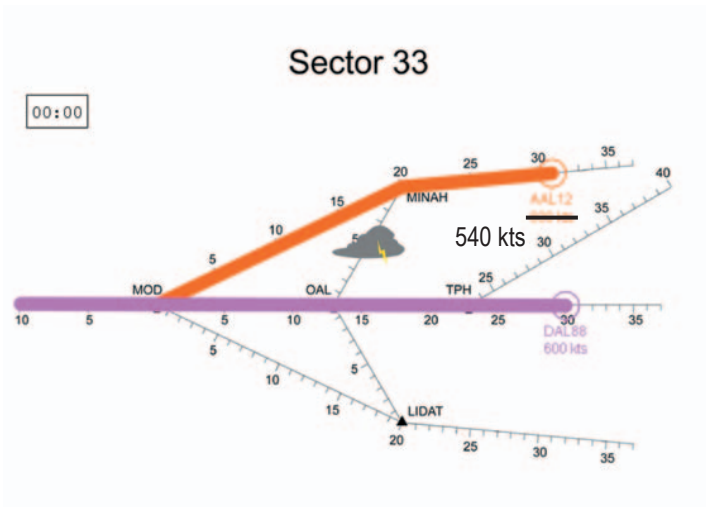• **AAL12** needs to slow down to fall back 2 Nmiles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	DAL88	30	
2nd	AAL12	31	1

Initial:

DAL88 AAL12

Target:

2 Nmiles AAL12
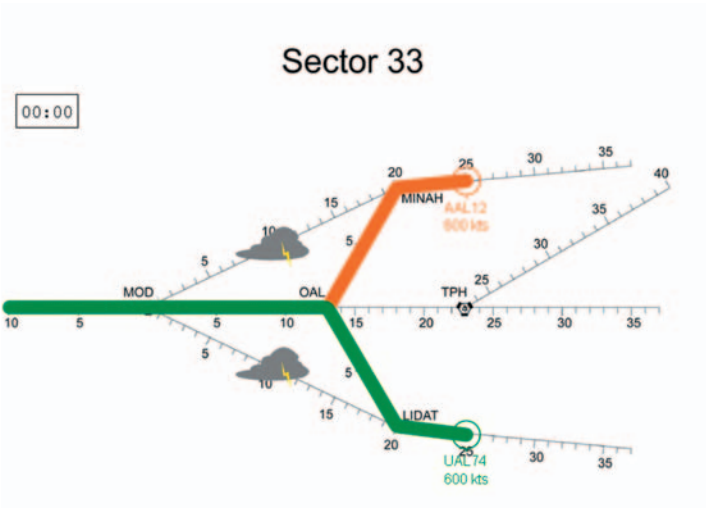
X   X

Solution:

Sector 33

00:00

540 kts

• **AAL12 -** Slow down to 540 knots for 2 minutes to fall back 2 Nmiles. Then speed up to 600 knots.

• **Target Time** - 3:18 mins.

Solution

Starting Conditions:

Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	28	600
UAL74	LIDAT	OAL	MOD	28	600

- Route from **MINAH** to **MOD is closed**.
- Route from **LIDAT** to **MOD is closed**.
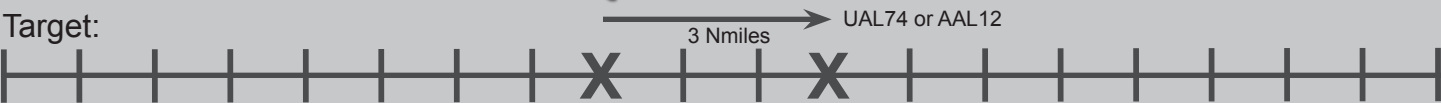- Ideal spacing at **MOD** - 3 Nmiles

Analysis:

- **Conflict:** AAL12 **AND** UAL74 will arrive at OAL at the same time.
- **Weather** prevents **AAL12 AND UAL74** from rerouting.
- UAL74 or AAL12 need to slow down to fall back 2 Nmiles by OAL **and** 3 Nmiles by MOD.

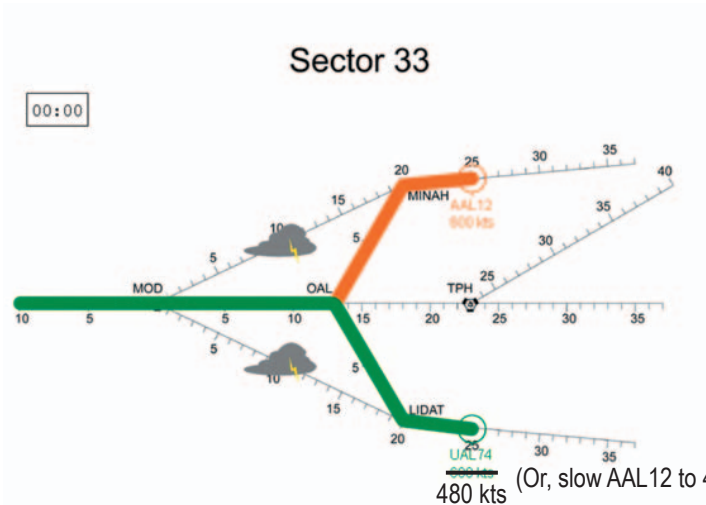| Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	28	0
1st	UAL74	28	

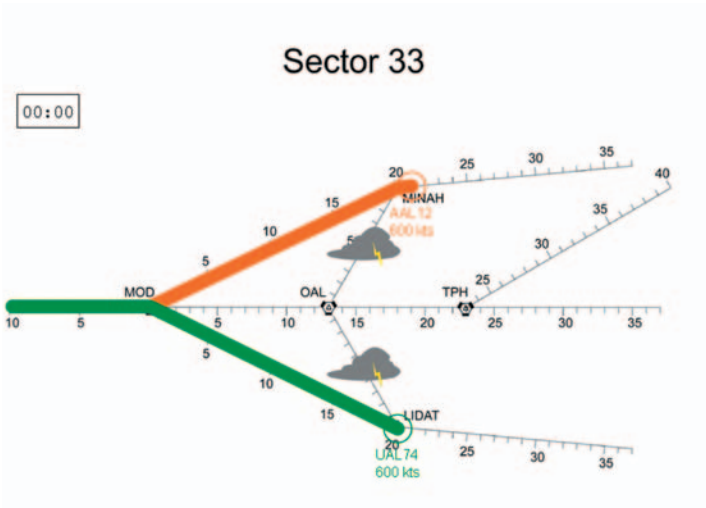Initial:

Target: 3 Nmiles — UAL74 or AAL12

Solution:

- **UAL74 or AAL12 -** Slow down to 480 knots for 1.5 minutes to fall back 3 Nmiles **at OAL**. Then speed up to 600 knots.

- **Target Time** - 3:06 mins.

(Or, slow AAL12 to 480 kts.)
480 kts

Solution

Starting Conditions:

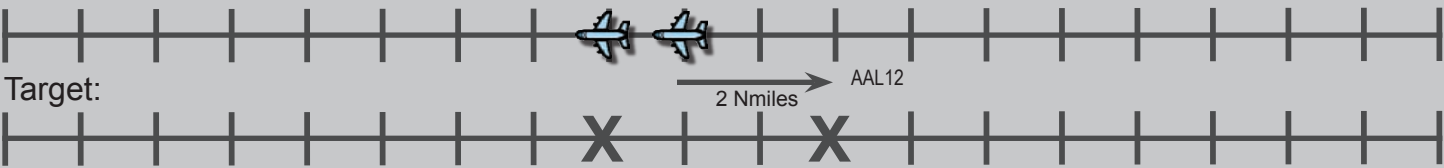| Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	21	600
UAL74	LIDAT		MOD	20	600

- Route from **LIDAT** to **OAL** is closed.
- Route from **MINAH** to **OAL** is closed.
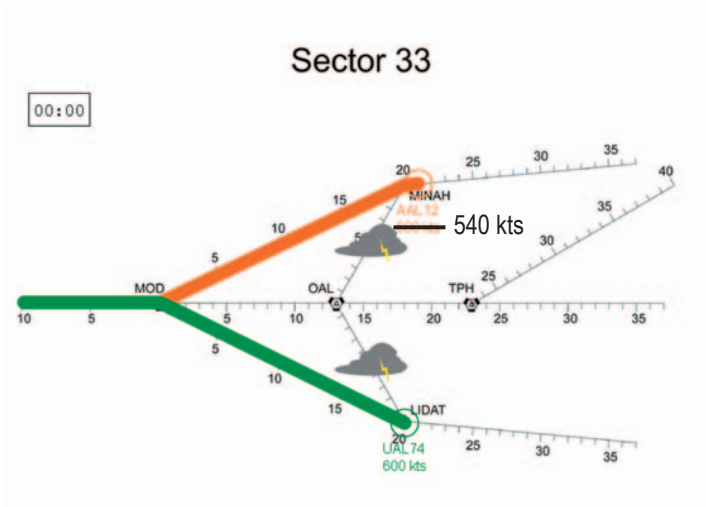- Ideal spacing at **MOD** - 3 Nmiles

Analysis:

- **Conflict: AAL12** will arrive at MOD **1 Nmile** behind **UAL74**.
- **Weather** prevents UAL74 or AAL12 from rerouting.
- **AAL12** needs to slow down to fall back 2 Nmiles.

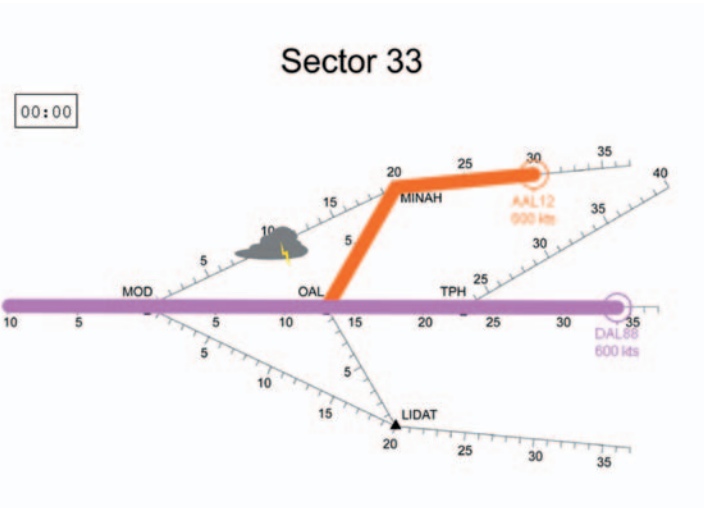| Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	20	
2nd	AAL12	21	1

Solution:

- **AAL12 -** Slow down to 540 knots for 2 minutes to fall back 2 Nmiles. Then speed AAL12 up to 600 knots.

- **Target Time** - 2:18 mins.

Problem 2-11   Solution

Starting Conditions:

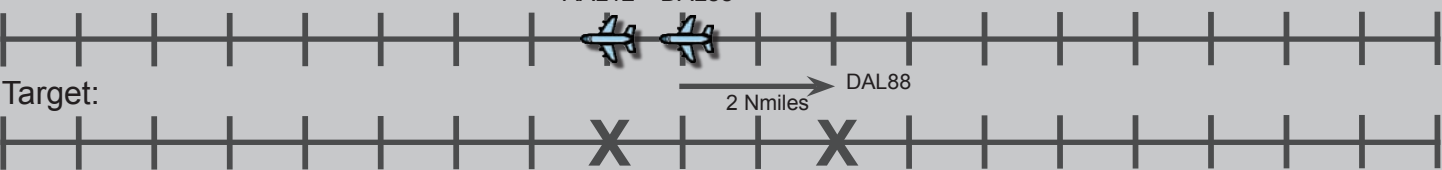| Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	33	600
DAL88	TPH	OAL	MOD	34	600

• Route from **MINAH** to **MOD is closed**
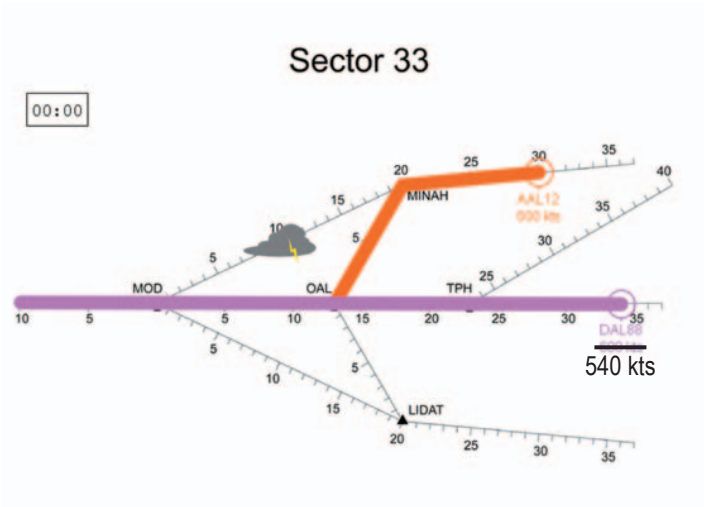• Ideal spacing at **MOD** - 3 Nmiles

Analysis:

• **Conflict: DAL88** will arrive at OAL **1 Nmile** behind **AAL12**.
• **Weather** prevents **AAL12** from rerouting.
• **DAL88** needs to slow down to fall back 2 Nmiles by **MOD** (and at least 1 Nmile by OAL).

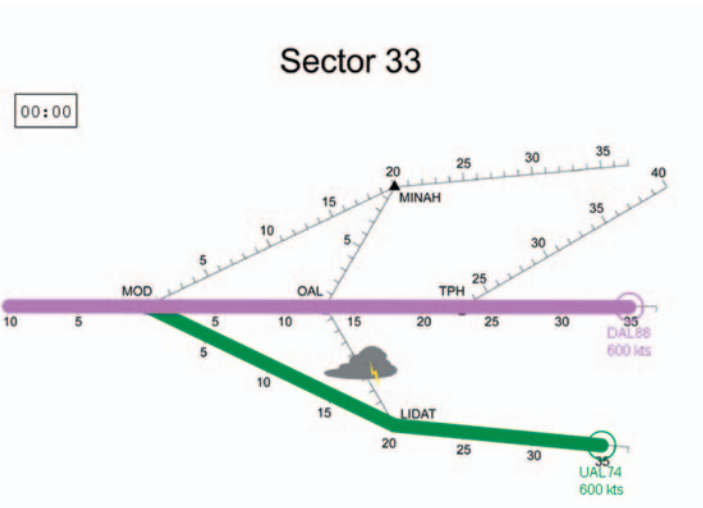| Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	33	1
2nd	DAL88	34	

Initial:

Target:

Solution:

• **DAL88 -** Slow down to 540 knots for 2 minutes to fall back 2 Nmiles. Then speed up to 600 knots.

• **Target Time** - 3:36 mins.

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Solution

Starting Conditions:

Sector 33

`00:00`

Plane	From	Through	To	Distance	Speed
DAL88	TPH	OAL	MOD	35	600
UAL74	LIDAT		MOD	35	600

- Route from **LIDAT** to **OAL is closed**.
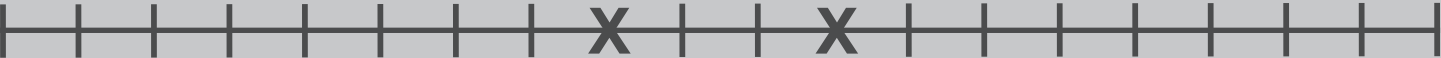- Ideal spacing at **MOD** - 3 Nmiles

Analysis:

- **Conflict:** **DAL88** **AND** **UAL74** will arrive at MOD at the same time.
- **Weather** prevents **UAL74** from rerouting.
- **UAL74** or **DAL88** need to slow down to fall back 3 Nmiles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	DAL88	35	0
1st	UAL74	35	

Initial:

DAL88 UAL74
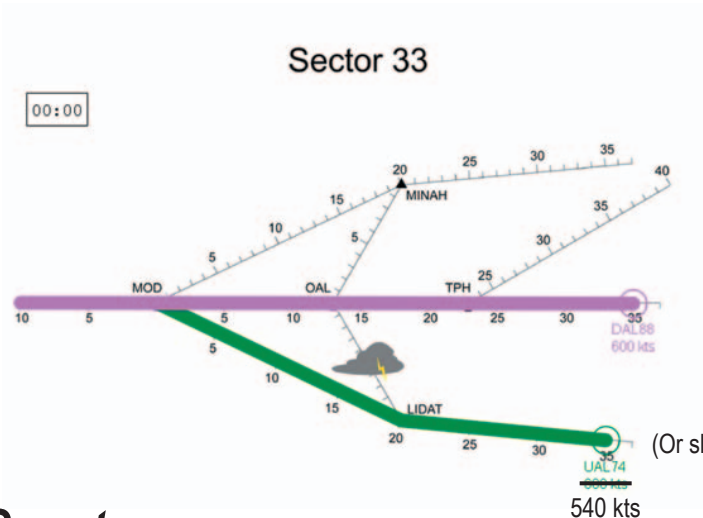
Target:

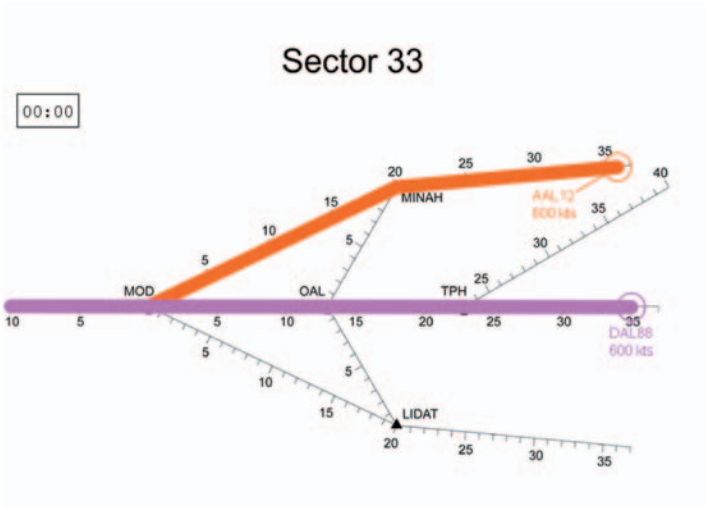3 Nmiles → UAL74 or DAL88

Solution:

Sector 33

`00:00`

- **UAL74 or DAL88 -** Slow down to 540 knots for 3 minutes to fall back 3 Nmiles. Then speed up to 600 knots.

- **Target Time** - 3:48 mins.

(Or slow DAL88 to 540 kts.)

540 kts

Smart Skies™

Solution

Starting Conditions:

Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	36	600
DAL88	TPH	OAL	MOD	35	600

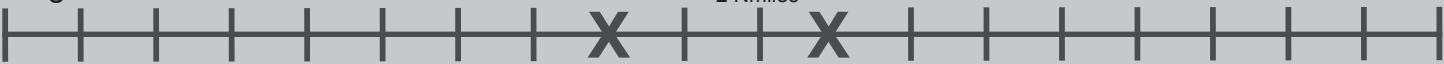• Ideal spacing at **MOD** - 3 Nmiles

Analysis:

• **Conflict:** AAL12 will arrive at MOD **1 Nmile** behind **DAL88.**

• **AAL12** needs to slow down to fall back 2 Nmiles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	DAL88	35	⟩→ 1
2nd	AAL12	36	

Initial:

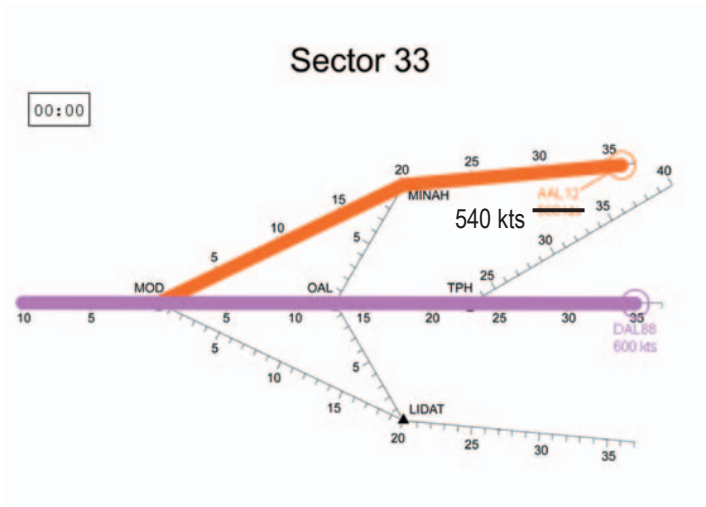DAL88 AAL12

Target:

2 Nmiles → AAL12

X   X

Solution:

540 kts

• **AAL12 -** Slow down to 540 knots for 2 minutes to fall back 2 Nmiles. Then speed up to 600 knots.

• **Target Time** - 3:48 mins.

Starting Conditions:
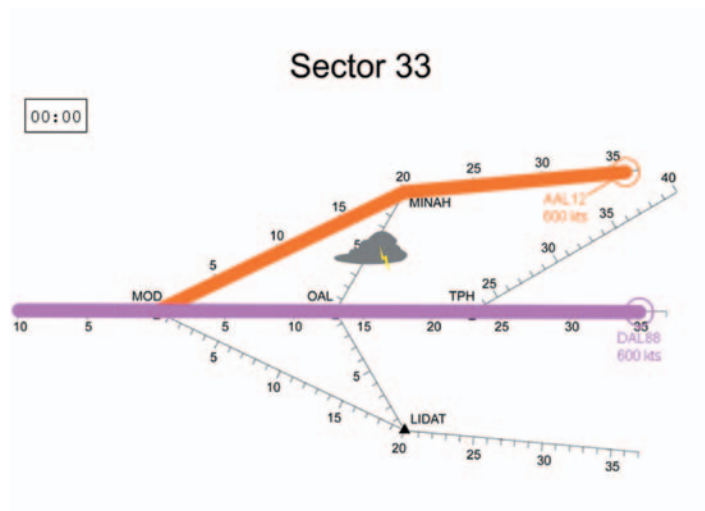
Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	36	600
DAL88	TPH	OAL	MOD	35	600

• Route from **MINAH** to **OAL** is closed.
• Ideal spacing at **MOD** - 3 Nmiles

Analysis:

• **Conflict: AAL12** will arrive at MOD **1 Nmile** behind **DAL88.**
• **Weather** prevents **AAL12** from rerouting.
• **AAL12** needs to slow down to fall back 2 Nmiles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	DAL88	35	⟩→ 1
2nd	AAL12	36	

Initial:

DAL88 AAL12
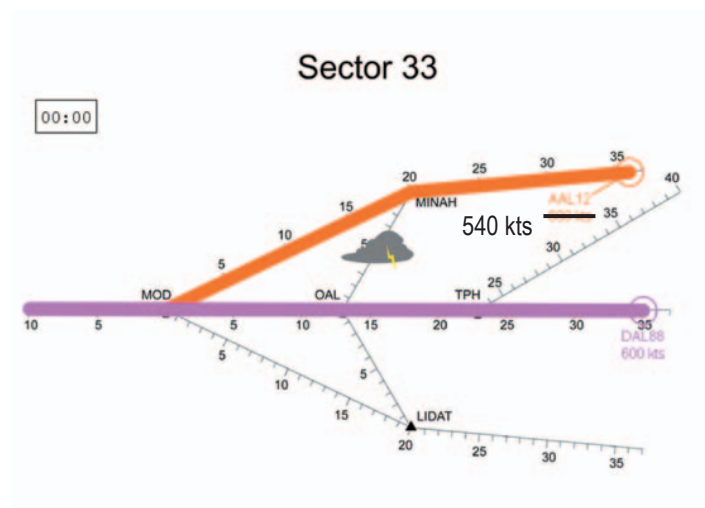
Target:

2 Nmiles → AAL12

X   X

Solution:

• **AAL12 -** Slow down to 540 knots for 2 minutes to fall back 2 Nmiles. Then speed up to 600 knots.

• **Target Time** - 3:48 mins.

Starting Conditions:

Sector 33

`00:00`

Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	30	600
UAL74	LIDAT		MOD	31	600

• Route from **LIDAT** to **OAL** is closed.
• Route from **MINAH** to **OAL** is closed.
• Ideal spacing at **MOD** - 3 Nmiles

Analysis:

• **Conflict: UAL74** will arrive at MOD **1 Nmile** behind **AAL12**.
• **Weather** prevents **UAL74** or **AAL12** from rerouting.
• **UAL74** needs to slow down to fall back 2 Nmiles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	30	
2nd	UAL74	31	1

Initial:

AAL12   UAL74

Target:

2 Nmiles → UAL74

X   X

Solution:

Sector 33

`00:00`

540 kts

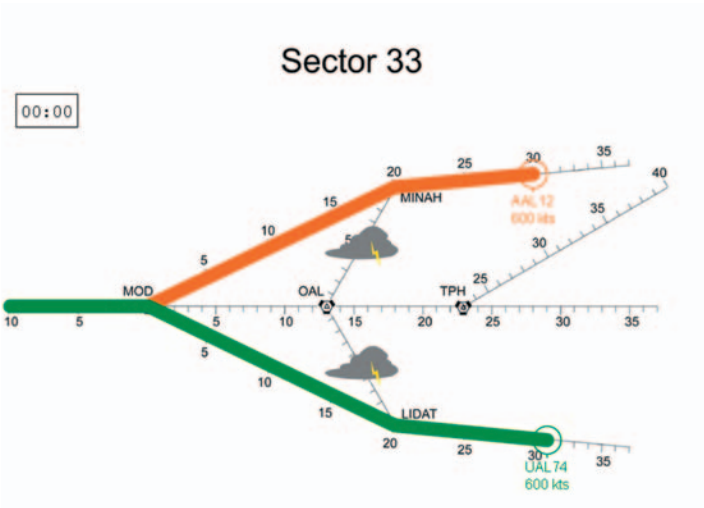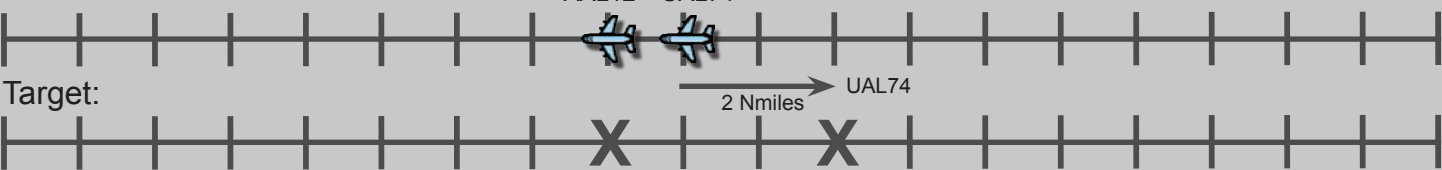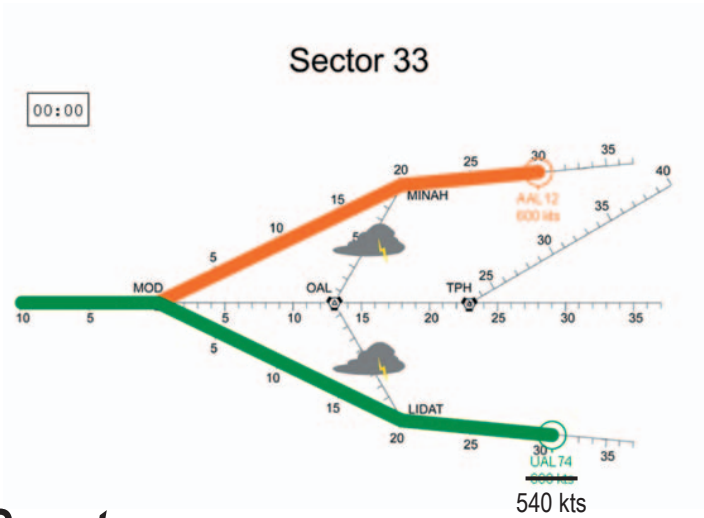• **UAL74 -** Slow down to 540 knots for 2 minutes to fall back 2 Nmiles. Then speed up to 600 knots.

• **Target Time** - 3:18 mins.

Starting Conditions:
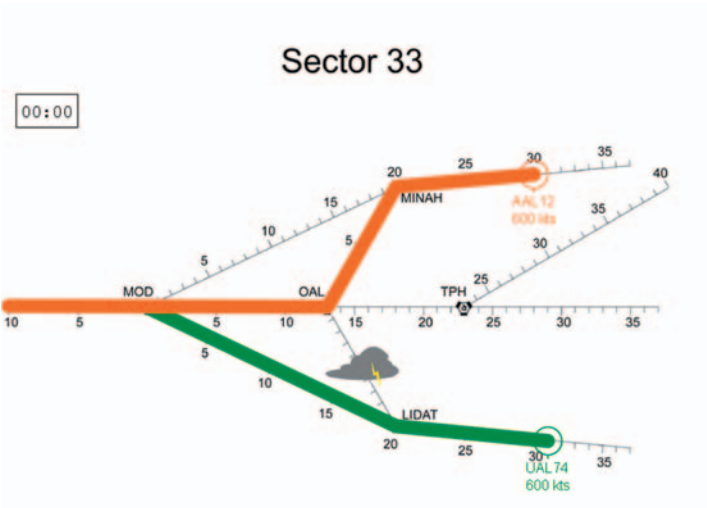
Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	33	600
UAL74	LIDAT		MOD	31	600

• Route from **LIDAT** to **OAL is closed**.
• Ideal spacing at **MOD** - 3 Nmiles

Analysis:

• **AAL12** will arrive at MOD **2 Nmiles** behind **UAL74**.
• **Weather** prevents UAL74 from rerouting
• **AAL12** can take the shortcut to shorten its travel distance by 3 Nmiles and move ahead of **UAL74** by 1 Nmile. **UAL74** can slow down to fall back 2 Nmiles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	31	2
2nd	AAL12	33	

Initial:

Target:

Solution:
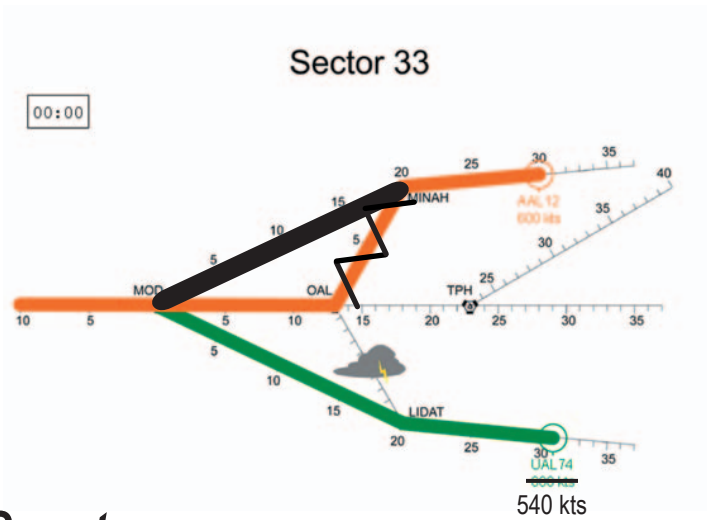
• **AAL12 -** Send direct MOD to move forward 3 Nmiles.
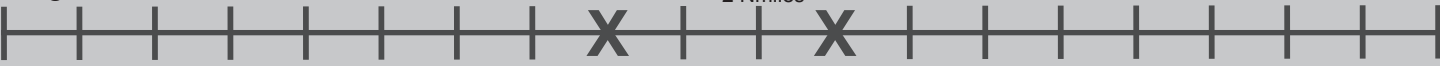• **UAL74 -** Slow down to 540 knots for 2 minutes to fall back 2 Nmiles. Then speed up to 600 knots.

• **Target Time** - 3:18 mins.

LineUp With Math™

Math-Based Decisions in Air Traffic Control

Student Workbook E

Appendix II

- Resolving Air Traffic Conflicts by Changing Speed
  - 2 planes, each at the same starting speed
  - Simulator Problems 2-4, 2-5, 2-6, 2-7, 2-8

Workbook Answers

▶ ▶ ▶

- Simulator at: www.atcsim.nasa.gov

Delta 88, reduce speed to five-four-zero knots.

Investigator: _____

An Airspace Systems Program Product

Investigator: _____

Ideal Spacing at MOD = 3 Nmiles
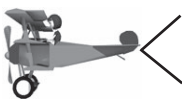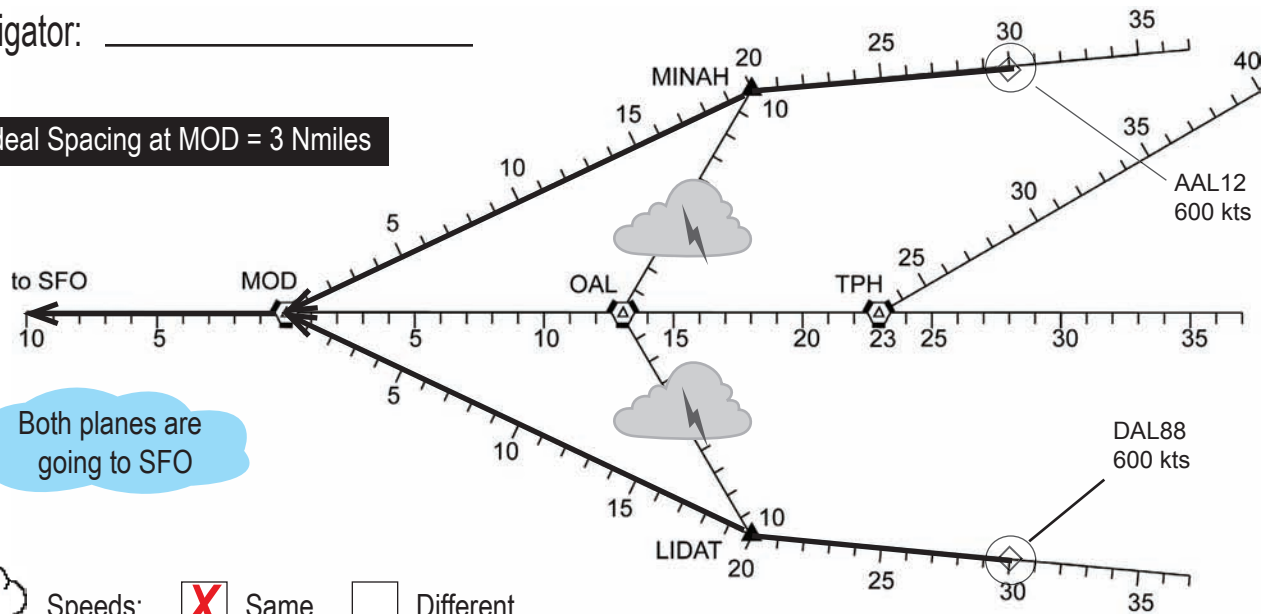
MINAH

AAL12
600 kts

to SFO   MOD   OAL   TPH

Both planes are
going to SFO

DAL88
600 kts

LIDAT

1 Speeds: **X** Same ☐ Different

2 Headstart = **0** Nmi = Separation at MOD

3 **Additional** Spacing Needed for Ideal Spacing (3 Nmiles) **3** Nmi

¤ To get the Ideal Spacing, you must change speed because the alternate routes are closed due to thunderstorms.

___ **How Much Time Before You Need Ideal Spacing?** ___

4 At 600 knots, how many minutes will it take the planes to reach MOD? **3** mins   600 kts = 10 Nmi/Min

$$30\,Nmi \div 10\,Nmi/min = 3\,mins$$

___ **What Speed Change Will Solve the Problem?** ___

¤ You can't speed up a plane because they are at the maximum speed of 600 kts.

5 Instead reduce the speed of one plane by 60 knots. Choose one plane to slow to 540 kts: *Either plane*

Remember: * A 60 knot difference in speed causes a 1 Nmile difference in distance each minute. 👉

6 At 540 kts, how many nautical miles *less* will this plane travel *each minute*? **9** Nmiles *per minute*

7 In 3 minutes, how much *additional* spacing will you gain due to the speed reduction? **3** Nmiles

$$1\,Nmi/min \cdot 3\,mins = 3\,Nmi$$

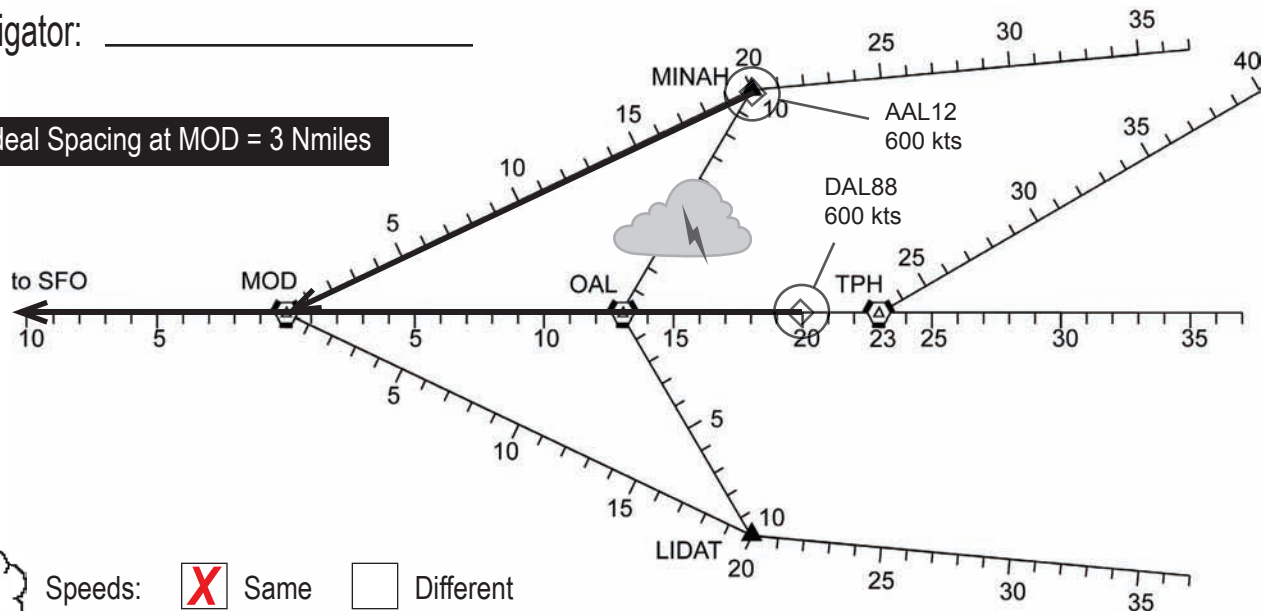**8** Does the 60-knot speed drop give Ideal Spacing at MOD? **X** Yes ☐ No

End of Worksheet

Investigator: _____

Ideal Spacing at MOD = 3 Nmiles

MINAH — AAL12 600 kts

DAL88 600 kts

to SFO — MOD — OAL — TPH

LIDAT

1. Speeds: **X** Same ☐ Different

2. Spacing at MOD = **0** Nmi

3. Additional Spacing Needed for 3 Nmiles = **3** Nmi

¤ You must change speed to meet the Ideal Spacing.

4. At 600 knots, how many minutes will it take the planes to reach MOD? **2** Minutes

600 kts = 10 Nmi/Min

$$20\,Nmi \div 10\,Nmi/min = 2\,mins$$

Remember: * Controllers change speed in 60 knot steps.
* A 60 knot difference in speed causes a 1 Nmile difference in distance each minute.

¤ First, slow AAL12 (or DAL88(by 60 knots, to

5. At MOD, how much spacing will you gain? **2** Nmiles *1 Nmi/min • 2 min*

6. Did the 60-knot speed drop give you Ideal Spacing at or before MOD? ☐ Yes **X** No

¤ Try a greater speed drop. Slow AAL12 by 60 + 60 = 120 knots, to 480 knots.

7. Now how much spacing will you gain at MOD? **4** Nmiles $2\,Nmi/min • 2\,min = 4\,Nmi$

8. Did the 120-knot speed drop give you Ideal Spacing at MOD? ☐ Yes **X** No

9. If No, what else could you do to get exactly Ideal Spacing at MOD?

Speed the plane back up when it has achieved 3 Nmi separation
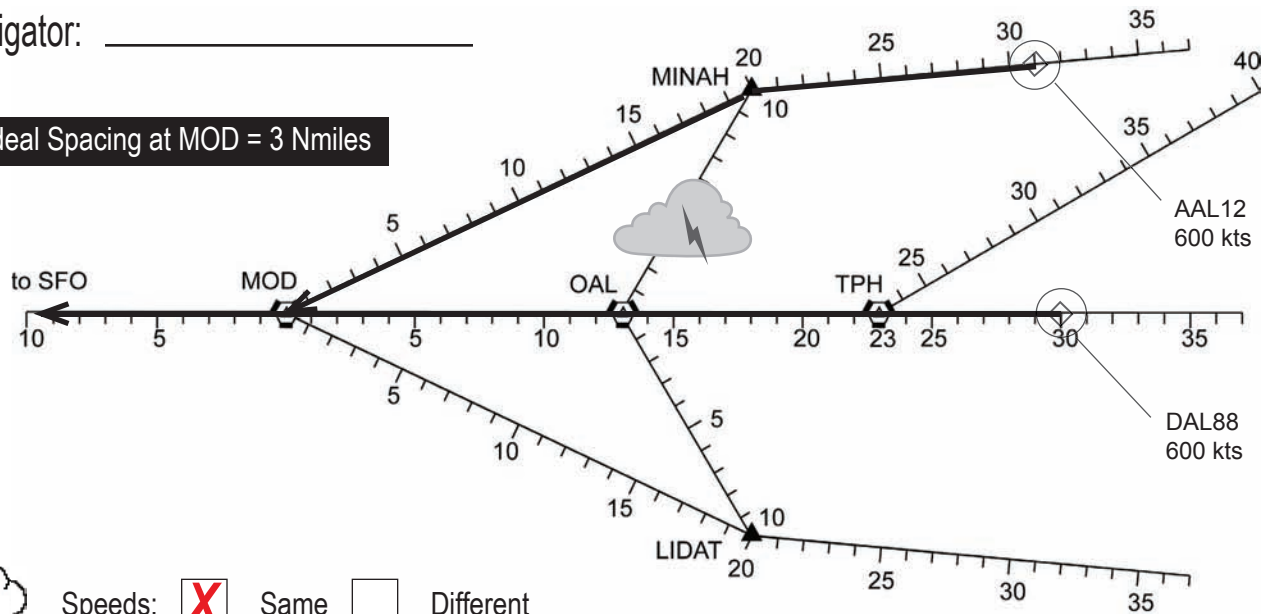
End of Worksheet

Investigator: _____

Ideal Spacing at MOD = 3 Nmiles

to SFO   MOD   OAL   TPH   MINAH   LIDAT

AAL12
600 kts

DAL88
600 kts

1. Speeds: **X** Same ☐ Different

2. Spacing at MOD = **1** Nmi
   31 - 30 = 1 Nmi

3. Additional Spacing Needed for 3 Nmiles = **2**

4. At 600 knots, how many minutes will it take the **lead** plane to reach MOD? **3** Minutes

   600 kts = 10 Nmi/Min

   30 Nmi ÷ 10 Nmi/min = 3 mins

¤ Controllers usually slow down the trailing plane (*not* the leading plane).

5. Which plane would a controller slow down to 540 knots? **AAL12** *(the furthest from MOD)*

   ¤ A 60 knot difference in speed causes a 1 Nmile difference in distance each minute.

6. At this speed, how many nautical miles less will this plane travel *each minute*? **1** Nmiles *per minute*

7. At MOD, how much *additional* spacing will be gained due to the speed reduction? **3** Nmiles

   1 Nmi/min • 3 min = 3 Nmi

8. What is the new spacing at MOD? **4** Nmiles

   3 Nmi + 1 Nmi headstart = 4 Nmi

9. Is the spacing ideal? ☐ Yes **X** No

10. If no, after how many minutes will you speed the plane up to 600 kts to make the spacing ideal at MOD? **2** Minutes

    With the 1 Nmi headstart, only need 2 Nmi extra. So speed up plane after 2 minutes.
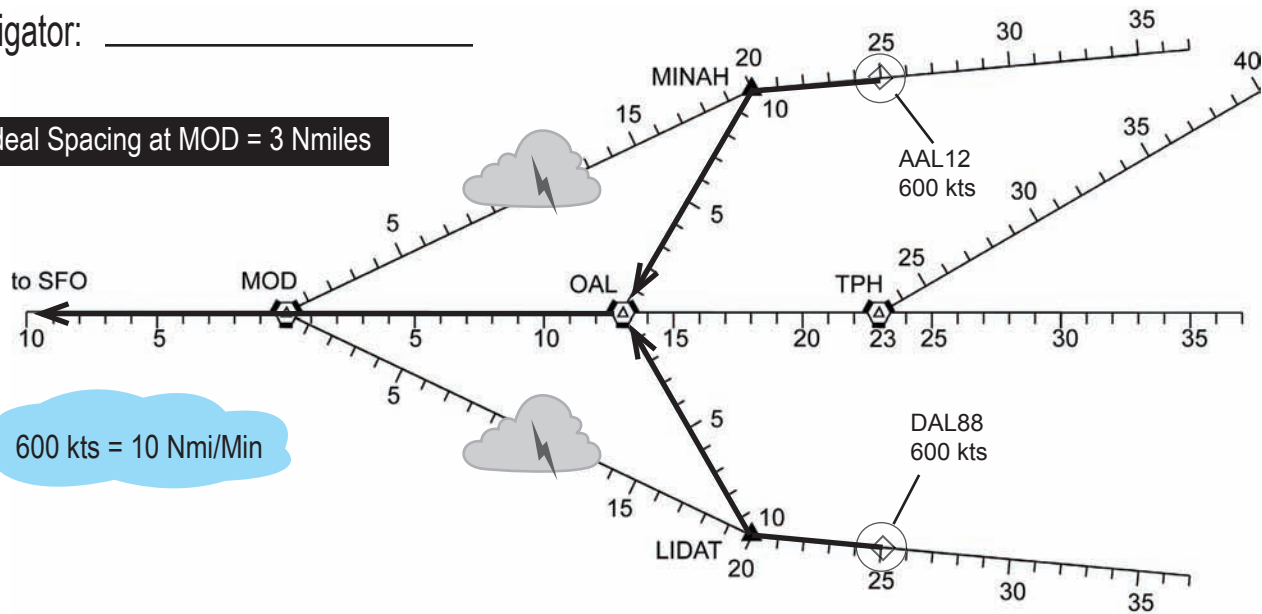
    End of Worksheet

Smart Skies™

Investigator: _____

Ideal Spacing at MOD = 3 Nmiles

MINAH · AAL 12 600 kts · 25 · 30 · 35 · 40

to SFO · MOD · OAL · TPH

600 kts = 10 Nmi/Min

DAL88 600 kts

LIDAT

Remember: * Controllers change speed in 60 knot steps.
* A 60 knot difference in speed will cause a 1 Nmile difference in distance each minute.

¤ Analyze the problem at **OAL** (routes first meet). MUST meet or exceed **minimum** separation of 2 Nmi.

1. Spacing at **OAL** = **0** Nmi ►► Additional Spacing Needed for **minimum** separation of **2** Nmiles **2** Nmi

5 - 15 = 0 Nmi

¤ Let' solve the problem by slowing one plane. Let's slow that plane to 540 kts.

2. Which plane will you slow? **Either plane**

3. At **OAL**, how much *additional* spacing will be added due to the speed *reduction*? **1.5** Nmiles

Faster plane will reach OAL in 1.5 mins. 1 Nmi/min • 1.5 mins = 1.5 Nmi

4. At 540kts, will the planes have at least **minimum** separation of 2 Nmi? **X** No ☐ Yes ►► If No, what new speed will you use? **480** kts

5. At the new speed, what will the separation be at OAL? **3** Nmi

2 Nmi/min • 1.5 mins = 3 Nmi

6. At your final speed change, do you get at least **Minimum** Separation at OAL? ☐ No **X** Yes

7. If Yes, when will you speed the plane up to 600 kts to get Ideal Spacing at **MOD**?

When faster plane arrives at OAL, speed up the slower plane to maintain 3 Nmi.

End of Worksheet

Understand the % Method

EXTENSION

¤ Now we will use a new method, the Percent Rule, to solve speed change problems.
Here's an example.

MOD

AAL12
600 kts

0   10   20 Nmiles

¤ At a speed of 600 knots, AAL12 travels 20 Nmiles to MOD in 2 minutes.

> 600 kts = 10 Nmi/Min

1 If we decrease the speed by 50% (that's 1/2 the speed), then the new speed is **300** knots

¤ At 300 knots (a 50% decrease in speed), AAL12 travels only 10 Nmiles (a 50% decrease) in 2 minutes.

¤ Here's a picture,

2 Minutes

20 Nmiles at 600 Kts

10 Nmiles at 300 Kts

MOD

AAL12

0   10   20 Nmiles
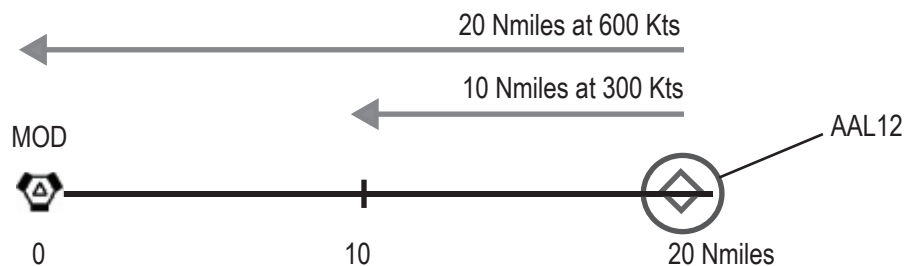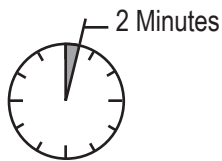
¤ So, in two minutes, we have:

Percent	Speed	Distance Traveled
100%	600 knots	20 Nmiles
50%	300 knots	10 Nmiles

¤ The 50% decrease in speed gives a 50% decrease in distance traveled in the same time.
This is an example of the Percent Rule:

> For a given amount of time, when you decrease a plane's speed by a given
> percent, the plane's distance traveled is decreased by the same percent.
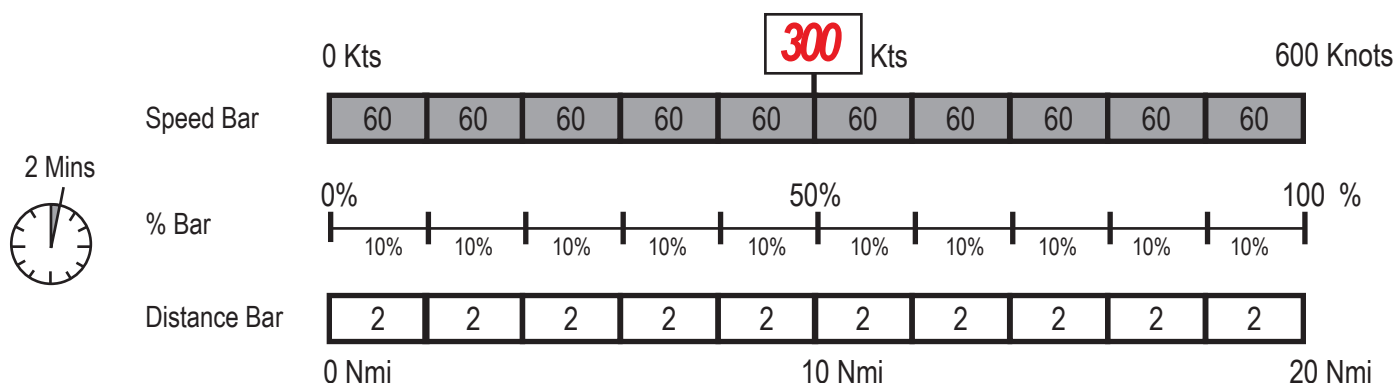
Continue to Next Page

% decrease in speed = % decrease in distance traveled

Here's the Percent Rule.

¤ Now we will use the Percent Rule to get additional spacing at MOD.

¤ In the picture below, the plane's maximum speed, 600 kts, is shown in 10% intervals (60 kts each) on the Speed Bar.

¤ The plane is 20 Nmiles from MOD.
   The distance to MOD is shown in 10% intervals (2 Nmiles each) on the Distance Bar.

0 Kts   **300** Kts   600 Knots

Speed Bar | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |

2 Mins

0%   50%   100 %

% Bar   10%   10%   10%   10%   10%   10%   10%   10%   10%   10%

Distance Bar | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

0 Nmi   10 Nmi   20 Nmi

2. Above the Speed Bar, in the empty box, fill in the plane speed that is 50% of 600 knots.

¤ Use this picture and the Percent Rule to answer Questions 3-5.

3. If we decrease speed by 60 knots, what is the % decrease in speed?   **10** %

4. Using the Percent Rule, what is the % decrease in distance traveled in two minutes?   **10** %

5. How many **fewer** nautical miles will the plane travel in two minutes??   **2** Nmi
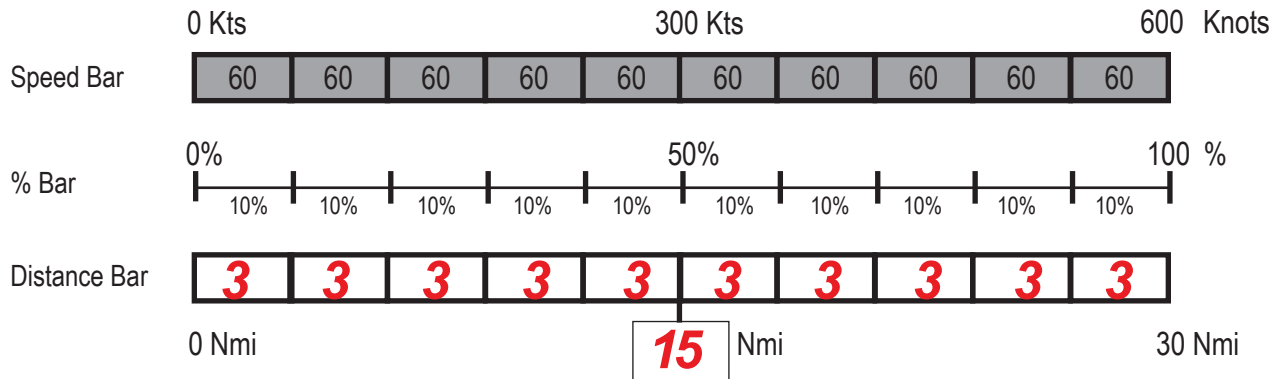
Continue to Next Page

¤   Now suppose the plane is **30 nautical miles** from MOD, traveling at 600 knots.

	0 Kts				300 Kts					600 Knots

Speed Bar
60	60	60	60	60	60	60	60	60	60

% Bar
0%   50%   100 %
  10%   10%   10%   10%   10%   10%   10%   10%   10%   10%

Distance Bar
3	3	3	3	3	3	3	3	3	3

0 Nmi   **15** Nmi   30 Nmi

7   In the box below the Distance Bar, fill in the distance that is 50% of the **30 Nmiles** to MOD.

8   The distance to MOD is 30 Nmiles. For each 10% interval, fill each Distance Bar box with the number that is 10% of 30 Nmiles.

¤   Use this picture and the Percent Rule to answer Questions 9-12.

9   If we decrease speed by 120 knots, what is the percent decrease in speed?   **20** %

10   Using the Percent Rule, what is the percent decrease in distance traveled in the same travel time?   **20** %

11   Using this percent, how many **fewer** nautical miles will the plane travel?   **6** Nmi

$$D = 20\% \text{ of } 30\,Nmi = 0.2 \cdot 30\,Nmi = 6\,Nmi$$

¤   Now the plane speed is **again** 600 knots.
The plane travels **30 nautical miles** to MOD in a certain amount of time.
But we don't need to know this time to answer this question.

Wow! We didn't need to find "time" to solve these problems!

12   To travel 9 **fewer** nautical miles (in this same time) by what percent would you reduce the plane speed ?   **180** %

13   By how many knots would you reduce the plane speed?   **180** Knots

$$3\,Nmi + 3\,Nmi + 3\,Nmi \Rightarrow$$
$$60\,kts + 60\,kts + 60\,kts = 180\,kts$$

End of Worksheet

Investigator: _____

Ideal Spacing at MOD = 3 Nmiles

MINAH · AAL12 600 kts · TPH · MOD · OAL · to SFO · UAL 74 600 kts · LIDAT
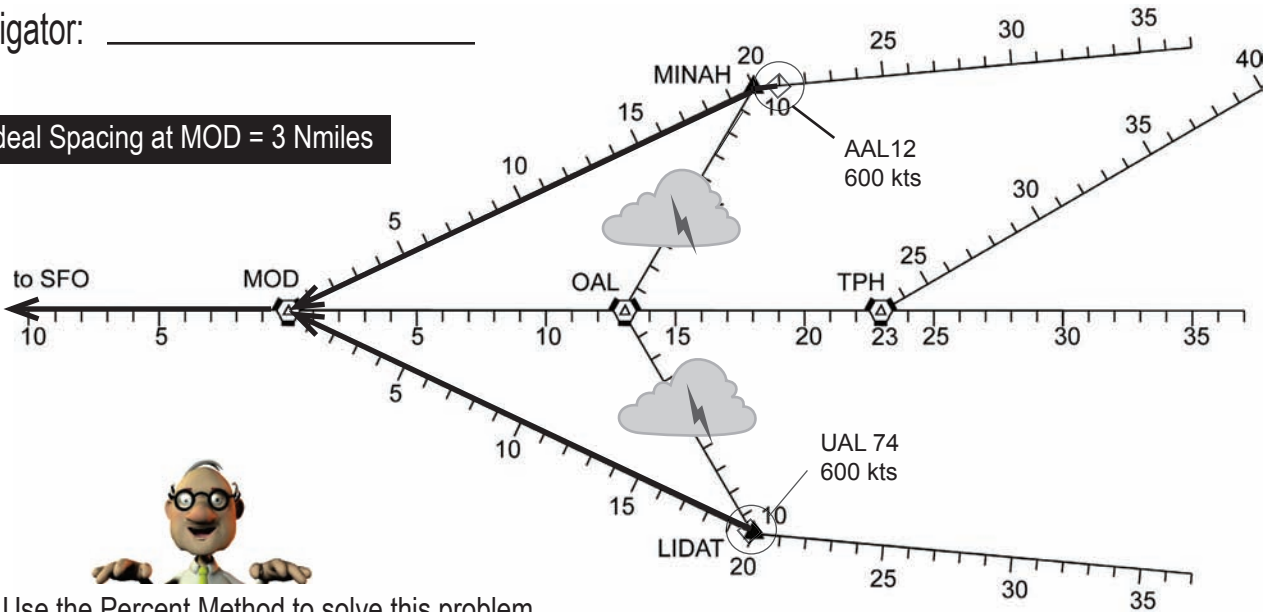
¤ Use the Percent Method to solve this problem.

1 Lead plane = **UAL74** Spacing at MOD = **1** Nmi   Additional Spacing Needed for 3 Nmiles = **2** Nmi

21 - 20 = 1 Nmi

¤ To achieve Ideal Spacing at MOD, decrease the speed of the trailing plane.

2 How many Nmiles does the *lead* plane travel to MOD? **20** Nmiles

3 When the lead plane reaches MOD, the *trailing* plane has traveled **[X] the same** [ ] a different distance.

¤ To get the additional spacing when the lead plane reaches MOD, decrease the trailing plane's 20-Nmi travel distance by **2** Nmiles.

4 What is the percent decrease in travel distance for the trailing plane?

$$\% \text{ Decrease} = \frac{\text{Additional Spacing Needed}}{\text{Distance Traveled}} = \frac{2 \text{ Nmiles}}{20 \text{ Nmiles}} = \frac{1}{10} = \boxed{10} \%$$

5 For the trailing plane: to decrease its travel distance by 10%, decrease its speed by **10** %.

6 If you decrease the trailing plane's speed by 10%, what is its new speed? **540** knots

7 What is the new spacing at MOD? **3** Nmiles

600 - (10% of 600) =
600 - 60 = 540 kts

End of Worksheet